International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249-6890; ISSN (E): 2249-8001
Vol. 9, Issue 2, Apr 2019, 871-878

PERFORMANCE AND EMISSIONS OF CI ENGINE OPERATED WITH LINSEED OIL BIODIESEL-DIESEL BLENDS UNDER VARIED COMPRESSION RATIO

AVINASH KUMAR NAMDEO[1] & RAJESH GUPTA[2]

[1] *Research Scholar, Mechanical Engineering Department, M. A. N. I. T. Bhopal, Madhya Pradesh, India*

[2] *Professor, Mechanical Engineering Department, M. A. N. I. T. Bhopal, Madhya Pradesh, India*

ABSTRACT

This paper shows the effects of changing fuel blend ratio and compression ratio on performance and emissions of a CI engine operated with blends of linseed oil biodiesel with diesel. Linseed oil biodiesel was prepared by transesterification process of raw linseed oil. The test engine was a single cylinder, four stroke, variable compression ratio (VCR), direct injection diesel engine with necessary instruments and computer interface to measure and record the performance and exhaust emission variables. During the experiments, percentage of linseed oil biodiesel in the blends was varied from 0% to 100% by volume, while the compression ratio was varied from 15 to 20. Injection variables were not changed from manufacturer's settings (injection pressure 220 bars and injection timing 23º BTDC). The results revealed improvement in brake thermal efficiency and lowered emissions of carbon monoxide (CO), hydrocarbons (HC) when fuel blends were enriched with biodiesel. Increasing the compression ratio also improves engine performance and reduces emissions of CO and HC. However, nitrogen oxides (NO_x) increased with increase in biodiesel content of the blend as well as with increase in compression ratio. Further, it was concluded that linseed oil biodiesel has potential to replace conventional diesel.

KEYWORDS: Linseed Oil Methyl Ester, Variable Compression Ratio, Combustion, NO_x Emissions & VCR Engine

Received: Feb 14, 2019; **Accepted**: Mar 04, 2019; **Published**: Apr 05, 2019; **Paper Id.**: IJMPERDAPR201985

Original Article

INTRODUCTION

Due to increasing demand for fossil fuels and stringent emission regulations, researchers are searching for a sustainable alternative fuel for CI engines which can reduce toxic tailpipe emissions. Biodiesel is one of the most promising fuel, which burns in a very similar manner as of conventional diesel fuel. They can be easily used in conventional diesel engines and no modification is required in engine configuration. The total carbon emissions into the atmosphere is also very less for biodiesel fuels when compared with that of fossil diesel. Biodiesels are usually methyl or ethyl esters of fatty acids which are obtained by transesterifying a variety of vegetable oils or animal fat. The demand of edible oils for domestic purpose makes non edible oils more preferable for production of biodiesel fuels [1-9]. Linseed oil is one of the inedible oil that can be converted into linseed oil methyl ester (LOME), a biodiesel fuel for CI engines.

LITERATURE REVIEW

Earlier studies shows improved performance like BTE, BSFC, etc… and reduced emissions of CI engine for all blends of LOME. B20 is the found to be the optimum fuel blend [2, 10]. Long-term endurance tests of diesel

engines operated with LOME fuel revealed lower ash content and reduced wearing of vital parts by about 30% [11]. Beg et. al. [12] reported decrease in BTE, increase in exhaust gas temperature, CO emissions and smoke density are and decrease in NOx emissions for linseed oil biodiesel blends as compared to standard diesel fuel. Salvi et. al. [13] found improvements in BMEP and indicated thermal efficiency by 8 to 11 %, specific fuel consumption by 3.5 to 6 % for B10 blend at full load. They also reported reduced emissions of CO, HC and smoke while increased NOx emissions as compared with standard diesel fuel. Bhusnoor et. al. [14] varied the injection timing and injection pressure of a diesel engine operating on blends of diesel with linseed oil biodiesel and revealed that engine operated much better with advanced injection timing than for increased injection pressure in terms of its performance and exhaust emissions. Puhan et al. [15, 16] varied the fuel injection pressure from 200 to 240 bars in steps of 20 bars and found that 240 bars is the optimal injection pressure in terms of thermal efficiency. They also found reduced CO, HC and smoke emissions while increased NOx emissions as compared to diesel. Kumar and Khare [17] carried out experimental investigations for macro-emulsions of linseed oil in CI engines in alcohol. Their investigations manifested that alcohol concentration up to 10% in linseed oil macro-emulsion resulted in acceptable engine performance without noise. The highest thermal efficiency was found to be higher than that of neat diesel when 60% of diesel, 30% of linseed oil and 10% of methanol was used. Waynick [18] reviewed relevant fuel pump, injector and vehicle fleet tests. He reported the problem of engine deposits due to the presence of high levels of glycerine and acyl glycerides in the fuel. Quick et. al [19] used straight linseed oil and found extremely severe injector fouling and ring sticking occurred in less than 10 hours during the engine testing. Linseed oil's high viscosity results in poor atomization of fuel sprayed. Due to this, deposits in combustion chamber occur and unburned fuel is introduced in the lubricating oil. These problems can reduce engine life.

These investigations indicate that the use of linseed oil biodiesel fuel in diesel engines will provide a good opportunity to replace petroleum based diesel with a renewable and sustainable fuel. A little work has been done to improve the engine performance and reduce emissions by changing blend ratio or injection timing. But, the effect of compression ratio is yet to be studied, when CI engine is operated with blends of LOME biodiesel. Therefore, present work focuses the above concern, and experiments were conducted with various blend proportions and compression ratios.

MATERIALS AND METHOD

LOME is prepared from raw linseed oil, which is highly viscous than conventional diesel. Higher viscosity could lead to poor atomization of fuel and as a consequence, poor combustion and other engine problems may arise. Therefore, viscosity of raw oil is reduced by the process of transesterification [2, 20-29]. Blends of LOME were formed by direct mixing of LOME and diesel. The selected proportion of LOME in the blend are 0%, 10%, 20%, 30%, 40% and 100%. The measured fuel properties of LOME and its blends with diesel are summarized in Table 1.

Table 1: Properties of Diesel and different LOME Blends

Properties	Diesel	Linseed Oil	(LOME)					ASTM Standard D 6751-02
			LOME 10	LOME 20	LOME 30	LOME 40	LOME 100	
Density (kg/m^3)	830	914	835.9	841.8	847.7	853.6	889	870-900
Viscosity at 40^{o}C (cSt)	2.7	36.52	2.9	3.11	3.33	3.56	5.2	1.9-6.0
Flashpoint (^{o}C)	65	244	91	108	130	146	170	>130
Fire Point (^{o}C)	78	281	98	122	142	158	182	-
Calorific value (MJ/kg)	44.8	39.3	44.36	43.72	43.08	42.44	38.6	-

The engine used for current study is a single cylinder, four-stroke, water cooled computerized multi-fuel, variable compression ratio engine with necessary instrumentation and computer interface as shown in Figure 1. The other detailed specifications of the engine are shown in Table 2.

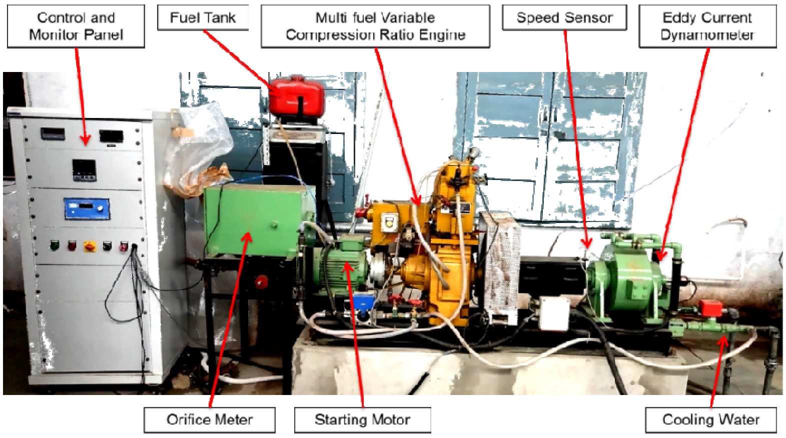

Figure 1: Schematic diagram of the Experimental Setup

Table 2: Engine Specifications

Sr. No.	Specification	Details
1	No. of cylinders	One
2	Cycle of operation	Four stroke
3	Bore	87.5 mm
4	Stroke	110 mm
5	Rated Power	4 bhp at 1500 rpm at compression ratio of 16.5:1
6	Cubic Displacement	661 c. c.
7	Compression ratio	12:1 to 20:1

The engine was started with standard diesel fuel at a speed of 1500 rpm for the tests. When the engine attained its operating temperature, load was applied and increased gradually to maximum rated load. Meanwhile, the computer interface stored performance and emission measurements. Compression ratio was also varied in steps of 15:1, 16.5:1, 18.5:1 and 20:1. Performance of engine for each fuel blend was measured similarly. AVL make gas analyser AVL_CDS250 was used to record the measured exhaust gas emissions. The specifications of AVL gas analyser are listed in Table3.

Table 3: Specification of AVL Gas Analyser and other Equipment

Sr. No.	Measured Quantity	Accuracy	Uncertainty
1	CO	±0.02% vol.	±0.2 %
2	HC	±4 ppm	±0.2 %
3	NO_x	±5 ppm	±0.1 %
4	CO_2	±0.3% vol.	±0.15 %
5	O_2	±0.02% vol.	±0.15 %
6	Pressure transducer	±0.5 bar	±0.2 %
7	Speed sensor	±2 rpm	±0.2 %
8	Load sensor	±0.5 N	±0.25 %
9	Fuel weight sensor	±3 grams	±0.3 %

RESULTS AND DISCUSSIONS

Brake Thermal Efficiency (BTE)

From Figure 2, it is clear that BTE increases as the blend is enriched with LOME. BTE is also found to be increased with increase in compression ratio of the engine for all fuels. At 20 CR the BTE of the engine operated with Linseed biodiesel is about 5% more than Diesel. This trend is also seen in earlier research [10, 12, 15, 16].

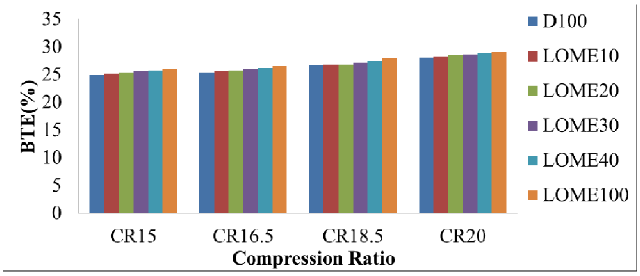

Figure 2: Brake Thermal Efficiency Vs Compression Ratio for different LOME blends

Brake Specific Fuel Consumption (BSFC)

Figure 3 shows that the BSFC increases with the increase in percentage of biodiesel in the blend. This may be due to the lower calorific values of biodiesel and short delay period. As compression ratio increases from 15 to 20, BSFC decreases for all biodiesel blends and for pure biodiesel. It is seen that the consumption of pure Linseed biodiesel is about 9% more at compression ratio of 20.

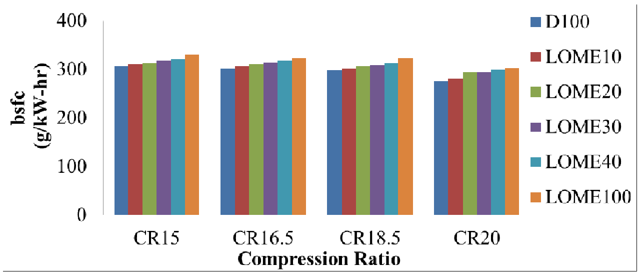

Figure 3: Brake Specific Fuel Consumption Vs Compression Ratio for different LOME blends

Carbon Monoxide (CO) Emissions

CO emissions are highly dependent on fuel properties, availability of oxygen, fuel mixing with air, temperature and turbulence of air inside the combustion chamber. Increase in compression ratios improves combustion, and therefore decreases CO emissions. This can be observed in Figure 4. It is also observed that as the blend gets richer in LOME, CO emissions are improved even at low compression ratios, and are much lesser at higher compression ratios. This is because of presence of oxygen atom in the molecule of biodiesel. CO emissions are about 83% less for pure Linseed biodiesel as compared to Diesel at compression ratio of 20.

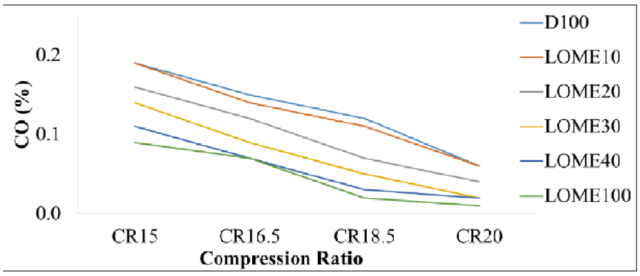

Figure 4: Variation of Carbon Monoxide with Compression Ratio for different LOME Blends

Hydrocarbon (HC) Emissions

HC emissions indicate incomplete combustion of fuel. It is evident in Figure 5, that rising compression ratio causes significant reduction of HC emissions for all the fuel blends. It can also be observed that, HC emissions are reduced with increase in percentage of LOME in the blend for all compression ratios. The oxygen atom present of in the molecule of biodiesel causes more complete combustion of biodiesel fuel blend. HC emissions were found reduced by about 72% for LOME100 fuel at CR20.

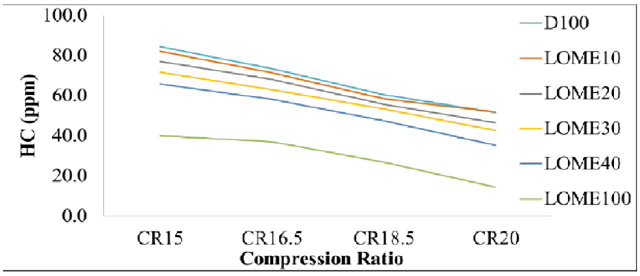

Figure 5: Variation of Hydrocarbon with Compression Ratio for different LOME Blends

Nitrogen Oxide (NO_x) Emissions

NO_x emissions are highly sensitive to combustion temperature. As the temperature of combustion reaches 2000 K or more, the rate of formation of NO_x increases. Biodiesels burn at much higher temperature than standard diesel so they cause higher NO_x emissions than diesel fuel. Increase in compression ratio also causes higher temperature of combustion and therefore higher NO_x emissions, which can be seen in Figure 6. NO_x emission is found to be increased as the percentage of LOME in the blends increase. NO_X emissions for LOME100 fuel are found to be increased by 10% to 11% at compression ratios from 15 to 20.

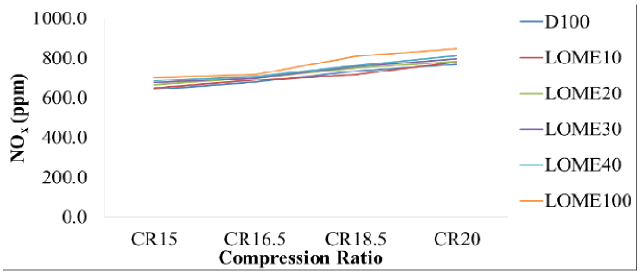

Figure 6: Variation of Nitrogen oxides with Compression Ratio for different LOME Blends

Smoke Opacity

Figure 7 shows the comparison of the smoke emission measurement of the engine for biodiesel blend and conventional diesel. Higher smoke emission occurs as biodiesel blends gets is enriched with LOME as compared to pure biodiesel. It is also evident that smoke emission reduces with the of increase compression ratio. Smoke emissions are reduced up to 45% for LOME20 fuel.

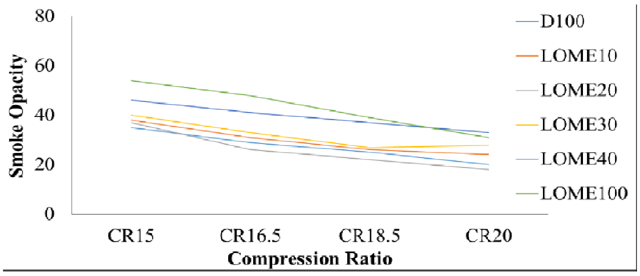

Figure 7: Smoke Vs Compression Ratio for different LOME blends

CONCLUSIONS

It was observed that linseed oil biodiesel is compatible with conventional CI engine without any modification in engine hardware. It is also observed that increasing the fuel blend ratio and compression ratio have vital effects on the performance of the engine. At CR 18.5, BTE and BSFC were improved by about 5% and 9%, respectively. CO and HC emissions were improved upto 83% and 72% respectively, when LOME100 fuel is used at CR20. But NOx emissions were raised by 10 to 11%, approximately. Smoke opacity was found to be lowest for LOME 20 at CR16.5, which is improved nearly by 45%. From the results of this study, it has been concluded that LOME 100 and its blends show superior performance and emission than stranded diesel fuel. These results motivate to use LOME as a potential replacement for conventional diesel fuel both in blended or pure form.

REFERENCES

1. *Agarwal, A. K., & Das, L. M. (2001). Biodiesel Development and Characterization for Use as a Fuel in Compression Ignition Engines. J. Eng Gas Turbines Power, 123:440-447*
2. *Mahla, S. K., & Birdi, A. (2012). Performance and Emission Characteristics of Different Blends of Linseed Methyl Ester on Diesel Engine. International Journal on Emerging Technologies, 3(1):55-59*
3. *Salvi, B. L., & Panwar, N. L. (2012). Biodiesel resources and production technologies – A review. Renewable and Sustainable Energy Reviews, 16:3680–3689*
4. *No, S. Y. (2011). Inedible Vegetable Oils and Their Derivatives for Alternative Diesel Fuels in CI Engines: A Review. Renewable and Sustainable Energy Reviews, 15(1):131–49*
5. *Singh, S. P., & Singh, D. (2010). Biodiesel production through the use of different sources and characterization of oils and their esters as the substitute of diesel: A review. Renewable and Sustainable Energy Reviews, 14:200–216*
6. *Demirbas, A. (2009). Production of biodiesel fuels from linseed oil using methanol and ethanol in non-catalytic SCF conditions. Biomass and Bioenergy, 33:113-118*
7. *Hebbal, O. D., Reddy, K. V., & Rajagopal, K. (2006). Performance characteristics of a diesel engine with deccan hemp oil. Fuel, 85:2187–2194*

8. *Qi, D. H., Chen, H., Geng, L. M., & Bian, Y. Z. (2010). Experimental studies on the combustion characteristics and performance of a direct injection engine fueled with biodiesel/diesel blends. Energy Conversion and Management, 51:2985–2992*
9. *Rajasekar, E., & Selvi, S. (2014). Review of combustion characteristics of CI engines fueled with biodiesel. Renewable and Sustainable Energy Reviews, 35:390–399*
10. *Agarwal, D., Kumar, L., & Agarwal, A. K. (2008). Performance evaluation of a vegetable oil fuelled compression ignition engine. Renewable Energy, 33:1147–1156*
11. *Agarwal, A. K., Bijwe, J., & Das, L. M. (2003). Effect of Biodiesel Utilization of Wear of Vital Parts in Compression Ignition Engine. J Eng Gas Turbines Power, 125:604-611*
12. *Beg, R. A., Rahman, M. S., Bose, P. K., & Ghosh, B. B. (2002). Performance Studies on a Semi-Adiabatic Diesel Engine Using Vegetable Oil as Fuel. SAE International*
13. *Salvi, B. L., & Jindal, S. (2013). A Comparative Study of Engine Performance and Exhaust Emissions Characteristics of Linseed Oil Biodiesel Blends with Diesel Fuel in a Direct Injection Diesel Engine. Journal of the Institution of Engineers (India): Series C, 94:1–8*
14. *Bhusnoor, S. S., Babu, M. K. G., & Subrahmanyam, J. P. (2007). Studies on Performance and Exhaust Emissions of a CI Engine Operating on Diesel and Diesel Biodiesel Blends at Different Injection Pressures and Injection Timings. SAE International*
15. *Puhan, S., Jegan, R., Balasubbramanian, K., & Nagarajan, G. (2009). Effect of injection pressure on performance, emission and combustion characteristics of high linolenic linseed oil methyl ester in a DI diesel engine. Renewable Energy, 34:1227–1233*
16. *Puhan, S., Saravanan, N., Nagarajan, G., & Vedaraman, N. (2010). Effect of biodiesel unsaturated fatty acid on combustion characteristics of a DI compression ignition engine. Biomass and Bioenergy, 34:1079–1088*
17. *Bhaskar, K., Sassykova, L. R., Prabhahar, M., & Sendilvelan, S. (2017). Effect of dimethoxy-methane (C3H8O2) additive on emission characteristics of a diesel engine fueled with biodiesel. International Journal of Mechanical and Production Engineering Research and Development, 8(1), 399-406.*
18. *Kumar, N., & Khare, U. (2004). Use of Macro-Emulsion of Vegetable Oil in Compression Ignition Engine. SAE International*
19. *Waynick, J. A. Characterization of Biodiesel Oxidation and Oxidation Products. (2005). Fuels and Lubricants Research Division, Southwest Research Institute, San Antonio, Texas, United States*
20. *Quick, G. R., Wilson, B. T., & Woodmore, P. J. (1982). Injector-Fouling Propensity of Certain Vegetable Oils and Derivatives as Fuels for Diesel Engines. American Society of Agricultural Engineering. Fargo, ND, 239-46*
21. *Bhaskar, K., Sassykova, L. R., Prabhahar, M., & Sendilvelan, S. (2017). Effect of dimethoxy-methane (C3H8O2) additive on emission characteristics of a diesel engine fueled with biodiesel. International Journal of Mechanical and Production Engineering Research and Development, 8(1), 399-406.*
22. *Abbaszaadeh, A., Ghobadian, B., Omidkhah, M. R., & Najafi, G. (2012). Current biodiesel production technologies: A comparative review. Energy Conv., & Mgmt, 63:138–148*
23. *Lin, L., Cunshan, Z., & Vittayapadung, S. (2011). Opportunities and challenges for biodiesel fuel. Applied Energy, 88:1020–1031*

24. *Dhawane, S. H., Bora, A. P., Kumar, T., & Halder, G. (2017). Parametric optimization of biodiesel synthesis from rubber seed oil using iron doped carbon catalyst by Taguchi approach. Renewable energy, 105, 616-624.*

25. *Agarwal, A. K. (2007). Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines. Progress in Energy and Combustion Science, 33:233–271*

26. *Rao, Y. V. H., Voleti, R. S., Sitarama, R. A. V., & Reddy, P. N. (2009). Experimental investigations on Jatropha bio-diesel and additive in diesel engine. Indian Journal of Science and Technology, 2:0974–6846*

27. *Mathiyazhagan, M., Ganapathi, A., Jaganath, B., Renganayaki, N., & Sasireka, N. (2011). Production of bio-diesel from non-edible plant oil shaving high FFA content. International Journal of Chemical and Environmental Engineering, 2:119-122*

28. *Schuchardt, U., Sercheli, R., & Vargas, R. M. (1990). Transesterification of vegetable oils; a review. Journal of the Brazilian Chemical Society, 9:199-210*

29. *Miao, X., Li, R., & Yao, H. (2009). Effective acid-catalyzed transesterification for biodiesel production. Energy Conversion and Management, 50:2680–4*

30. *Sprules, F. J., & Price, D. (1950). Production of fatty esters. US Patent 2, 366–494*

31. *Georgogianni, K. G., Katsoulidis, A. K., Pomonis, P. J., Manos, G., & Kontominas, M. G. (2009). Transesterification of rapeseed oil for the production of biodiesel using homogeneous and heterogeneous catalysis. Fuel Processing Technology, 90:1016–22*

32. *Vyas, A. P., Verma, J. L., & Subrahmanyam, N. (2010). A review on FAME production processes. Fuel, 89:1–9*